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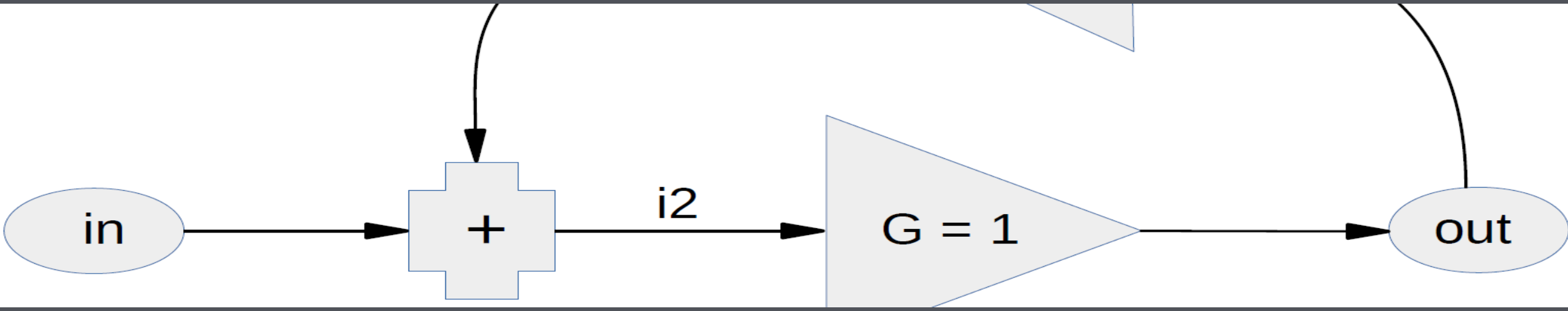
CHEMISTRY AND AEROSOL FEEDBACKS IN CRESCENDO EARTH SYSTEM MODELS

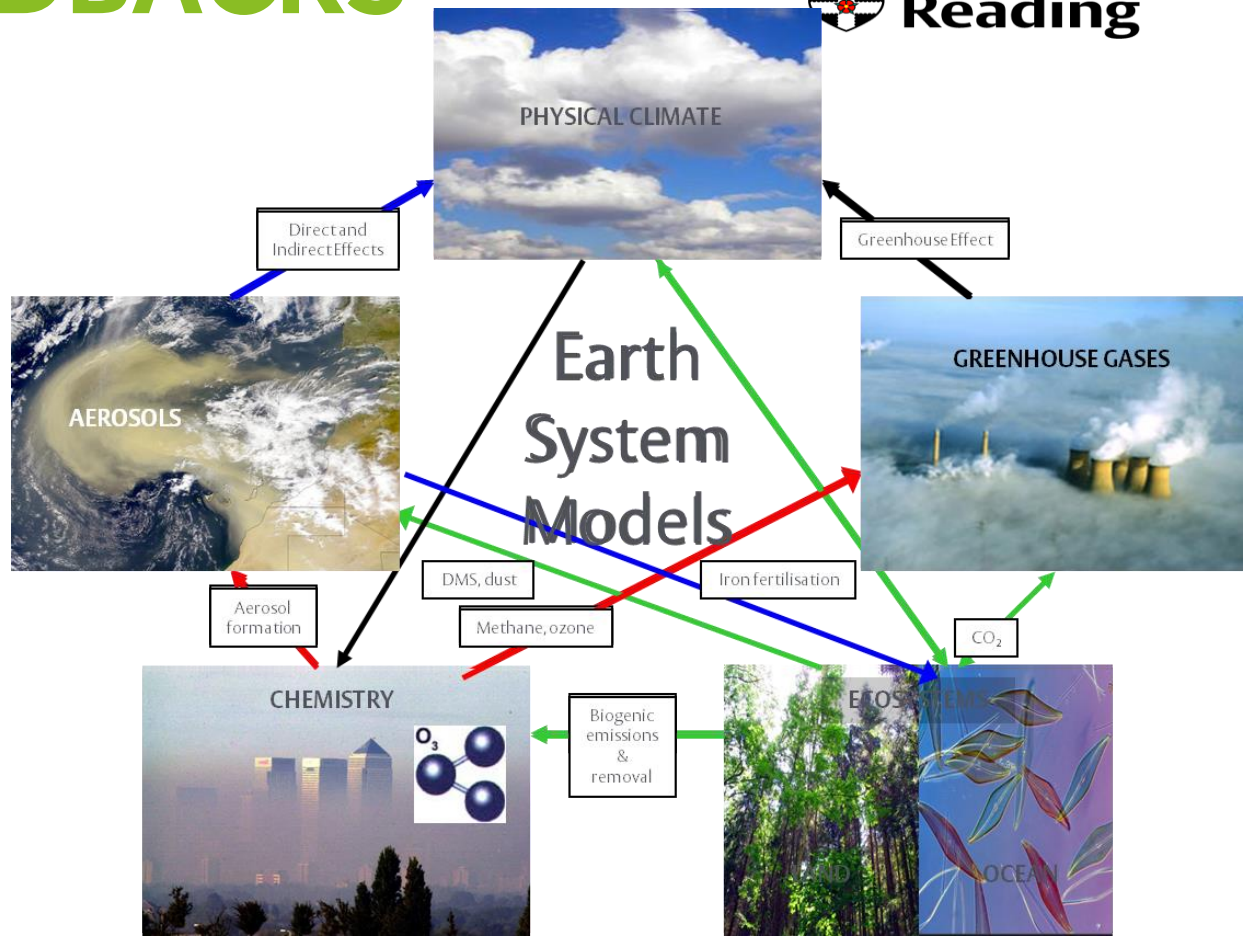
CRESCENDO



Bill Collins, Gill Thornhill, Dirk Olivie, Ramiro Checa-Garcia, Gerd Folberth, Ada Gjermundsen, Martine Michou, Jane Mulcahy, Pierre Nabat, Fiona O'Connor, Roland Seferian, Michael Schulz, Cat Scott,

CHEMISTRY SYSTEM FEEDBACKS

- CRESCENDO Earth system models include many more components than physical-only climate models
  - UKESM1, NorESM2, CNRM-ESM2-1,
    - +MIROC6, GFDL-ESM4, CESM2-WACCM, GISS-E2-1
  - Many more interactions between components
- These lead to extra feedbacks
- What does this imply for climate sensitivity?



KEY FEEDBACKS

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- Natural emissions
  - Dust
  - Sea salt
  - DMS
  - BVOCs
  - Lightning
  - Wetland methane
- Chemistry
  - Methane
  - Ozone

AEROSOLS

Dust

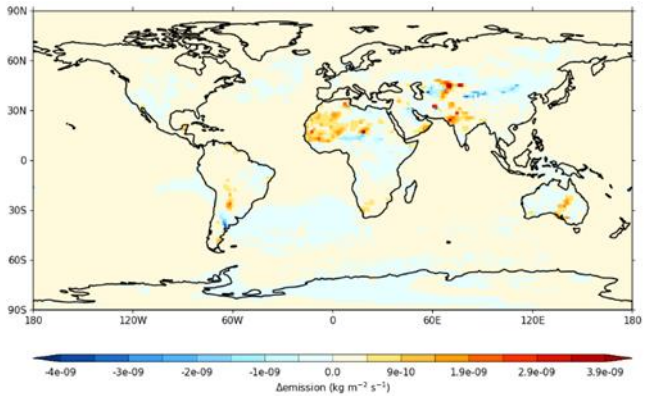
- Emission change uncertain
- ERF is small

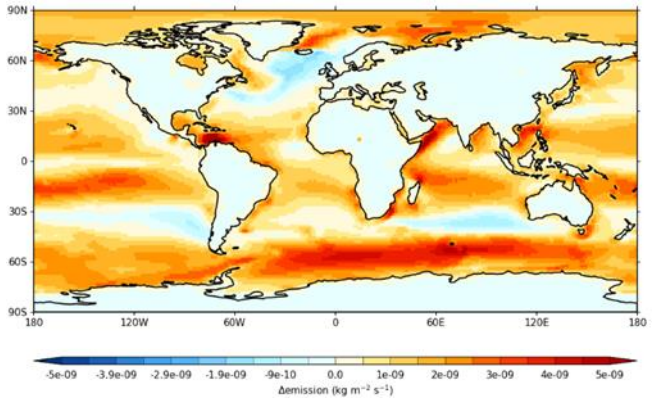
Sea salt

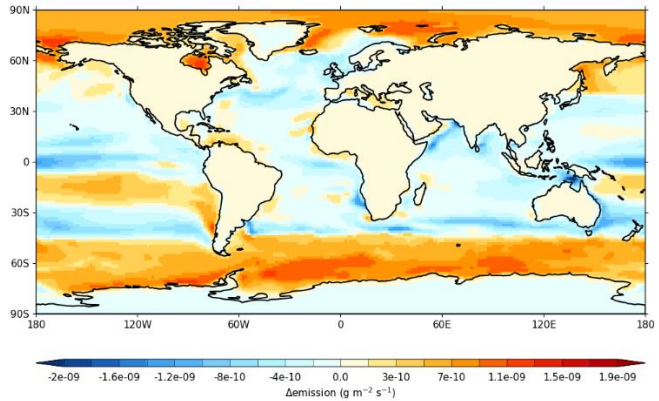
- Emissions increase
- ERF –ve

DMS

- Emissions increase and decrease
- ERF –ve

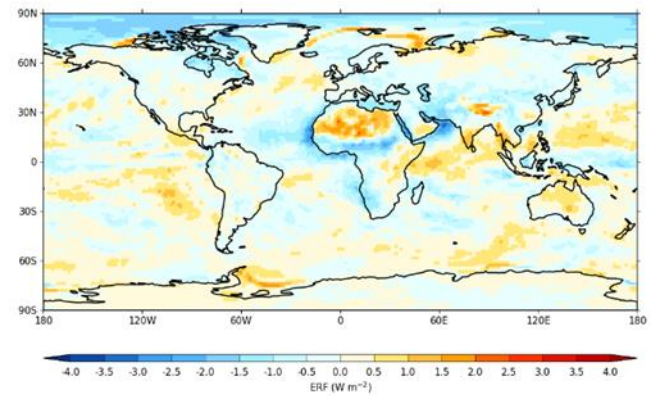


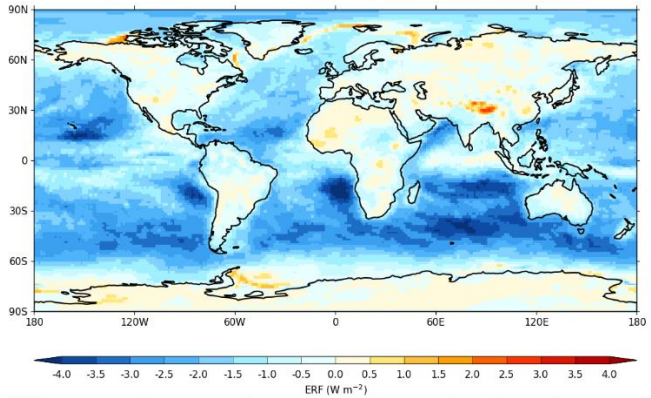


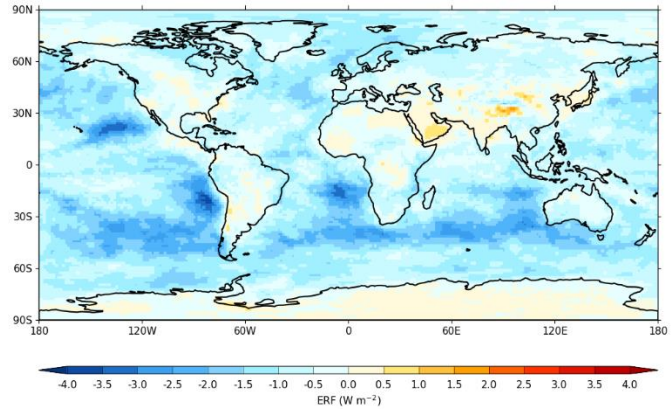


ΔEmissions

X







ΔForcing

=

Feedback

Small

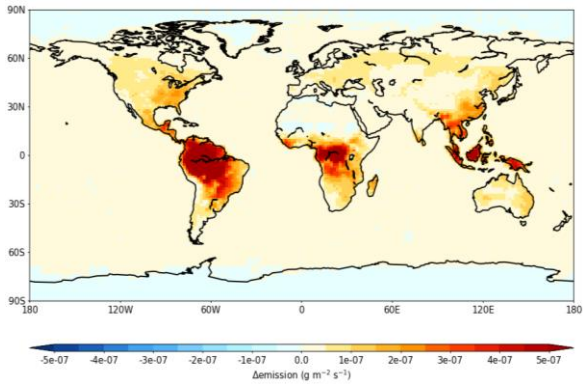
Large negative

Small positive

BVOCs

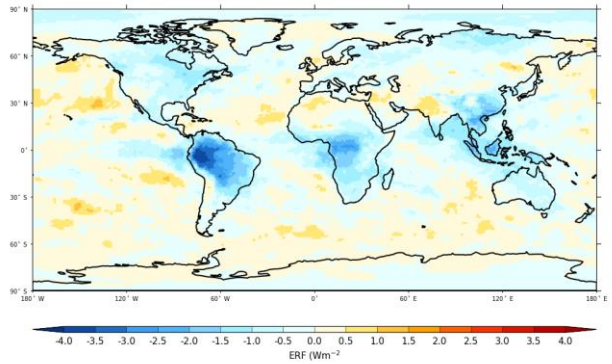
BVOCs

- Robust emissions increase
- ERF –ve
  - aerosol: -0.34 Wm^{-2}
  - ozone: +0.10 Wm^{-2}
  - Net -0.24 Wm^{-2}



ΔEmissions

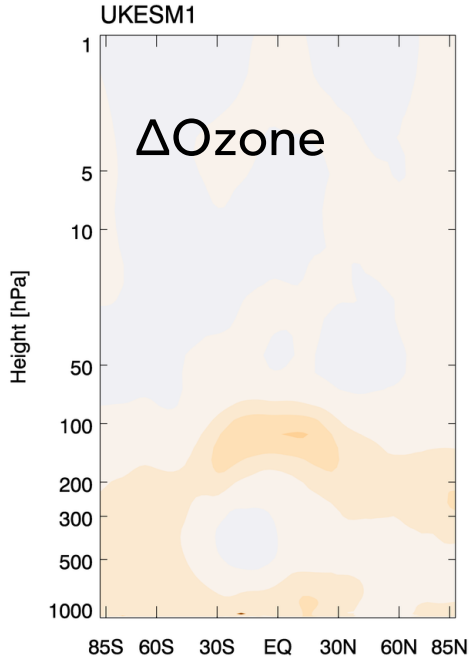
X



ΔForcing

= Large negative

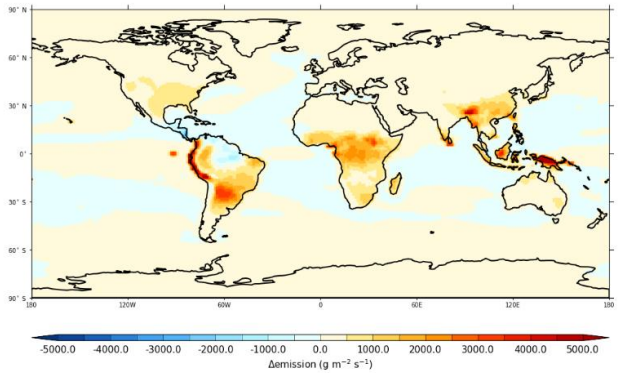
- Methane lifetime: +24% (+0.26 Wm^{-2})



LIGHTNING

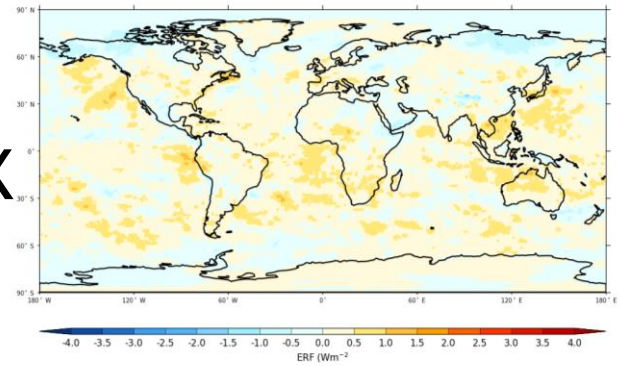
Lightning NOx

- Robust emissions increase
- ERF +ve but small
  - Ozone: +0.15 Wm^{-2}
  - Methane lifetime: -21% (-0.23 Wm^{-2})



ΔEmissions

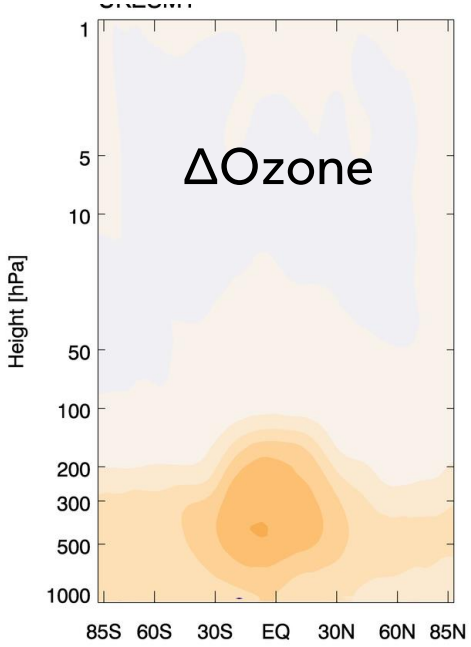
X



ΔForcing

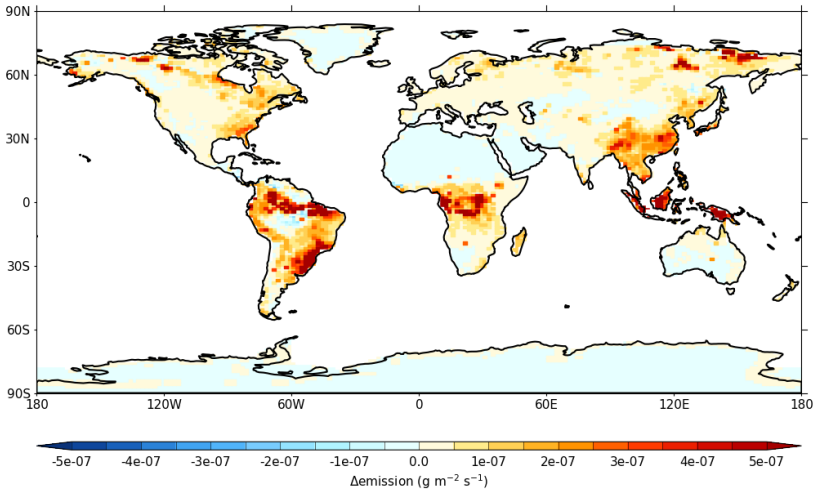
=

Small positive



WETLAND METHANE

- Wetland methane increases in 4xCO2
  - 300-500 Tg yr^{-1}
- Not possible to distinguish between the effect of temperature, and the effect of CO_2 on soil carbon



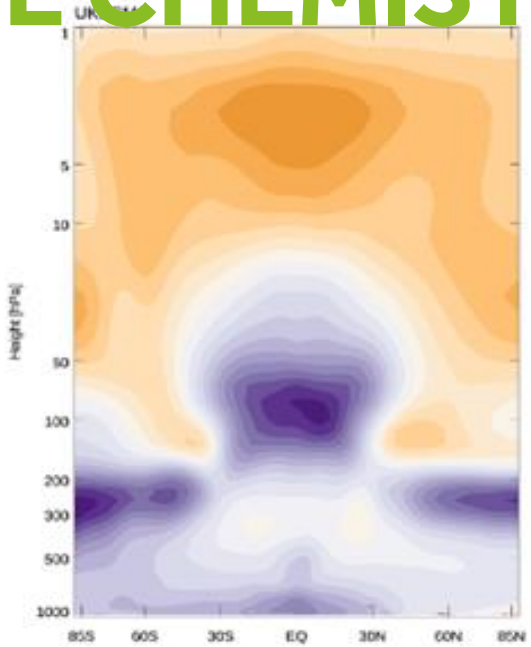
ΔEmissions

Large positive

OZONE AND METHANE CHEMISTRY

4xCO2

- Tropospheric ozone decreases
- Stratospheric ozone increases
  - Adjustment to CO2
- Net negative forcing (-0.26 Wm^{-2})



% decrease

Large negative

- Methane lifetime decreases ~-2%
  - after removing BVOC and lightning

Small negative

METHANE FEEDBACK

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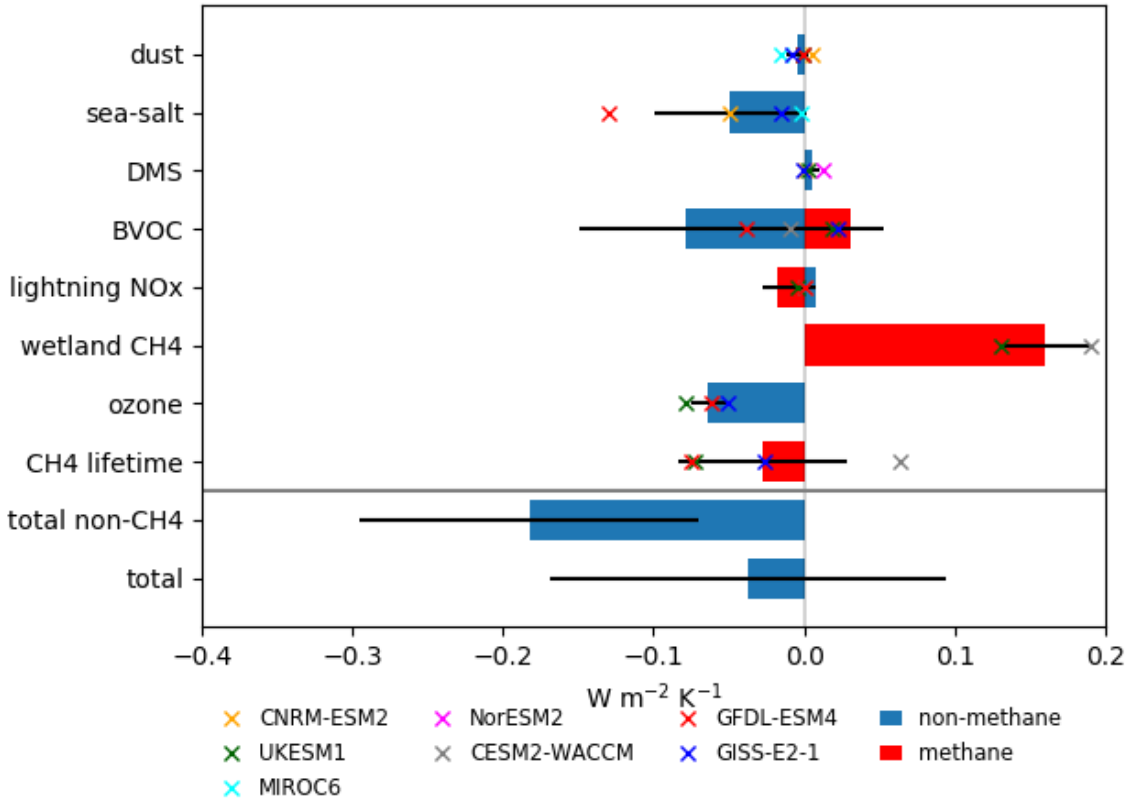
- These ESMs did not allow methane to vary
  - See Gerd Folberth's talk
- Changes in methane emissions or methane lifetime don't affect the climate sensitivity in these models
- We can calculate analytically the effects on climate sensitivity that would be expected in models with emission-driven methane

SYNTHESIS

- Combine:
  - Changes in emissions per K temperature change
  - Changes in forcing per emission
  - → Feedback
- Negative feedback -0.2 $Wm^{-2}K^{-1}$:
  - Increases in aerosols
  - Decreases in ozone
- Offset by increases in wetland methane.
- Smaller than physical feedbacks

Process	α_i (Wm^2K^{-1})
Water vapour	1.6±0.3
Lapse rate	-0.6±0.4
Albedo	0.3±0.1
Clouds	0.3±0.7

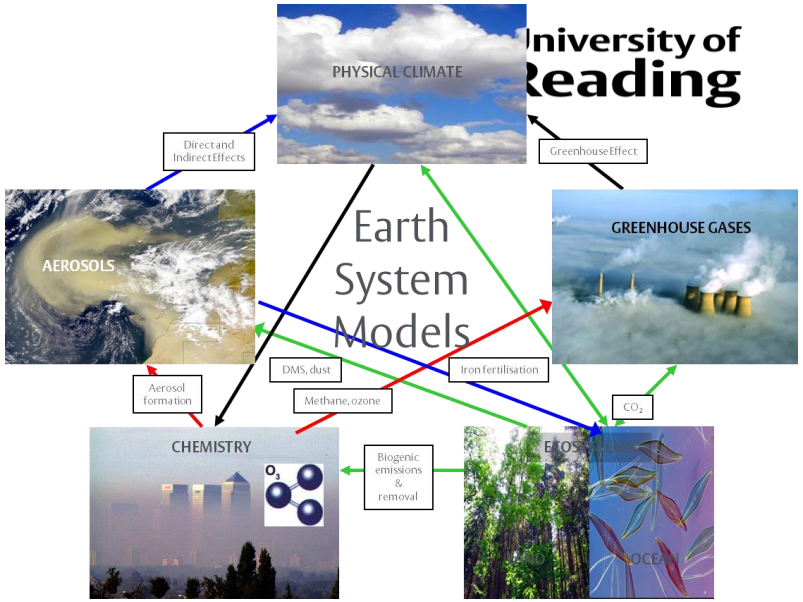
IPCC 2013



CONCLUSIONS

- Climate feedbacks through chemistry and aerosols are negative in Earth System models
  - (with prescribed methane)
- These models are likely to show a lower climate sensitivity than physical-only counterparts

- Models with interactive methane driven by emissions are likely to have a less negative feedback.



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